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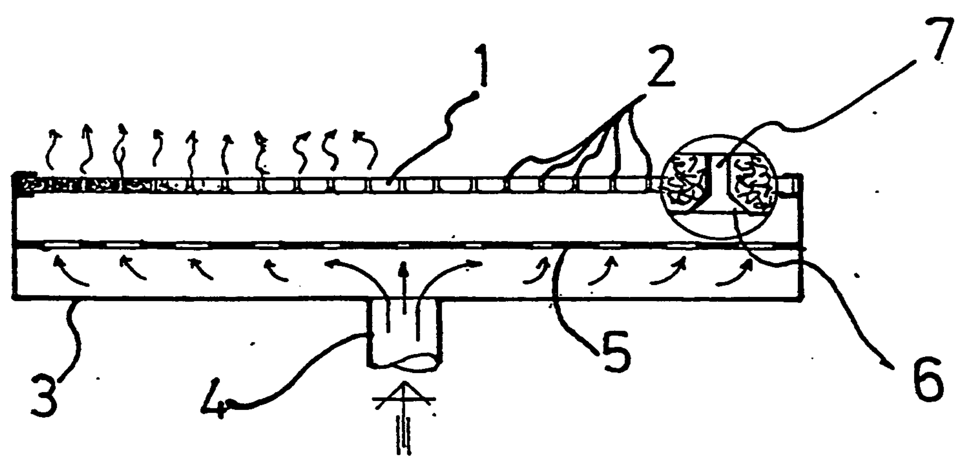

(57) Abstract

The invention relates to a porous metal fiber plate (1), in which a regular pattern of holes (2) has been made which occupy an overall free passage area of 5 % to 35 % of the total surface area of the plate, while each hole (2) has a surface area of between 0.03 mm^2 and 10 mm^2. The plate is suitable for use as a membrane in a gas burner device. The invention covers also a gas burner device in which such a porous metal fiber membrane is mounted.

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POROUS METAL FIBER PLATE

The invention relates to a porous metal fiber plate. Such plates, in which the fibers are sintered to one another, are used, among other things, as filter media.

It is further known from the European patent 0 157 432 to use these fiber webs as a membrane for radiant surface combustion burners for gas mixtures, in as far as steel fibers containing Cr and Al are used to make them resistant against high temperatures.

Since the porosity of these non-woven steels fiber webs, fiber mats or sintered fiber plates is not always perfectly homogenous, a uniform transverse gas flow over the entire surface of the plate cannot always be guaranteed. For a number of applications, this has turned out to be a drawback, e.g. for burner membranes and for the gas-permeable support plates for fluid bed treatments in which a controlled uniform flow is desired, linked with a small pressure drop across the thickness of the plate.

It is an object of the invention to avoid this disadvantage of the known gas-permeable metal fiber plates and thus to provide plates with a controlled uniform gas flow. According to the invention, this goal is achieved by providing a porous metal fiber plate in which a regular pattern of transverse holes or passages has been made which, all together, occupy an overall free passage area of 5 % to 35 % of the total surface area of the plate, while each hole has a surface area of between 0.03 and 10 mm^2. Thus the gas flow is forced primarily through these holes. This feature is favourable i.a. in view of achieving a small pressure drop across the plate.

Insofar as said plates need to be utilized at very high temperatures, the metal fibers that are used must be resistant to these temperatures. The equivalent fiber diameters may range between about 8 μm and 150 μm. With an equivalent fiber diameter is meant here the diameter of a fictive perfectly cylindrical fiber, the cross-section surface of which corresponds to the average cross-section surface of a real fiber which is not perfectly circular or even not circular at all. The thickness of the plate is preferably between 0.8 mm and 4 mm and the plate is sufficiently rigid and strong to resist the selected pressure drops at the desired porosities. Plate thicknesses of 1, 2 and 3 mm, for example, are suitable. The porous plate therefore does not need any extra support near its bottom surface or its top surface (e.g. with a steel plate). Thus the bottom and top surfaces remain freely accessible.

It is another object of the invention to provide a gas burner device comprising a housing with supply means for the gas to be burned, a distribution element for the gas stream and a porous metal fiber plate as a burner membrane which enables a controllable and uniform gas flow to the burner membrane exit surface and as a consequence a uniform burning process over the entire burner surface and with a low pressure drop in the gas flow crossing the membrane.

Yet a further object of the invention resides in the provision of a durable burner membrane wherein certain surface areas do not prematurely deteriorate due to overloading or overheating versus other areas, due to inhomogeneities in porosity thereby causing uncontrollable preferential gas glow paths and burning areas.

Another important object of the invention relates to the design of a porous metal fiber plate, usable as a burner membrane over an

enormously broad power range and which is therefor suitable for both surface radiant and blue flame modes.

A further object of the invention deals with the design of burner membrane plates which offer remarkably low CO and NO_x-emissions and high yields.

Yet another object of the invention concerns the design of a gas burner with less constraints as to prefiltration of the inflowing gas stream.

The provision of a gas burning device with less danger for resonances occuring in the gas stream and hence for avoiding whistling effects emerging during operation is to be considered a further object of the invention.

On the basis of several embodiments, further details will hereafter be explained. Additional solutions according to the invention for specific or partial problems or objectives and the characteristics of these solutions, as well as the advantages they entail, will also be made clear.

Figure 1 is a sketch of a porous plate with circular holes according to the invention.
Figure 2 shows one possible way of assembling this plate in a housing with supply means for the gas and transportation and flow means for it through the plate.
Figure 3 represents schematically a pipe-shaped device for passing the gas flow through.
Figures 4 to 7 relate to top views of several alternative patterns of transverse passages to be arranged in the porous plates.

Figure 8 shows a cross-section of a gas burner device according to the invention in which an acoustic muffling layer is clamped between the burner membrane and the distribution element.

Figure 9 presents a cross-section of a gas burner device in which a number of muffling layers are included, possibly along with empty interspaces.

The porous metal fiber plate 1 according to figure 1 comprises holes 2 spaced at regular distances p (pitch) from one another. These holes are by preference cylindrical in shape and, in particular, circular-cylindrical. By preference, the area of each hole 2 is the same and lies between 0.03 and 3 mm^2, though more preferably between 0.4 and 1.5 mm^2, respectively between 0.5 and 0.8 mm^2. As will be seen below, these dimensions are to be chosen i.a. depending on the thickness of the plate 1, its porosity and the intended application. When the hole 2 thus has a circular cross-section, the diameter of each circle will be 0.8 mm for a surface area of approximately 0.5 mm^2. The holes 2 are by preference made with a punching operation since this assures a smooth cylinder wall. If so desired, holes can also be punched with triangular, square, rectangular or other shapes. The holes may also be made with laser beams. Thus, in principle, very small holes with a diameter of at least 0.2 mm are possible for thin plates.

Figures 4 to 7 illustrate other preferred shapes of passages : slots of different shapes and their regular distribution over the plate surface. Two examples of a suitable regular pattern of adjacent rectangular slots 9 are shown in figure 4 (right side, resp. left side). Circular passages 2 and rectangular slots 9 can alternate over the surface as shown in figure 5. Similarly, oval or elliptic slots 11 can alternate with circular holes 2 as

represented in figure 7. A pattern of cruciform slots 10 is possible also as illustrated in figure 6. A great number of regular distributions of passages with different shapes is conceivable in view i.a. of minimizing or avoiding any whistling effect in the gas flow as will be explained further.

Each of the slots 9, 10, 11 should preferably have a surface area of between 1 and 10 mm^2. Rectangular, or substantially rectangular slots will have a slot width "w" of between 0,3 mm and 2 mm and a length "l" of between 3 mm and 20 mm. Preferably the relations 0,5 mm $\leq$ w $\leq$ 1 mm and 5 mm $\leq$ l $\leq$ 10 mm will apply. Anyway, in a plate with rectangular slots 9 according to e.g. figure 4 or 5, the overall free passage area occupies 20 % to 30 % of the total surface area of the plate.

The pitch p between adjacent holes 2 is chosen such that their total surface area comprises 5 % to 25 % of the total surface area of the plate, and preferably 8 % to 16 %. Values of 10 %, 12 % and 15 % are adequate. In order to assure a uniform flow over the surface, the successive holes are by preference ordered in a pattern of adjacent, equilateral triangles in which each hole 2 occupies a corner of the triangle.

The porosity of the plate (between the holes 2) is always between 60 % and 95 %, but preferably between 78 % and 88 %. The plate surfaces can be flat, can have a relief (be embossed), or else can be curved or corrugated, for example.

The metal fibers that can be used for producing the porous plates and the production of the plates themselves, and in particular those that are resistant against very high temperatures, are described in the same European patent application 390.255. In general, stainless steel fibers are suitable. For the high tempe-

rature applications, such as in gas burners, steel fibers containing Cr and Al are to be used, preferably those containing also a small amount of yttrium.

As represented in figure 2, the porous plate 1 according to the invention can be assembled in a standard manner in a housing 3 with supply means 4 for the gas. When this device is intended to function as a gas burner, a flammable gas mixture (e.g. natural gas/air) can be supplied. The device thus formed can, moreover, comprise a distribution element 5 for the incoming gas flow. Normally speaking, this will be a plate with suitable holes or passages arranged in it such that a uniform flow of gas with a suitable pressure reaches the inlet side of the porous plate 1. The surface area of the free passages in the distribution plate 5 can amount to between 2 % and 10 %. In the case of a cylindrical burner (figure 3), the distribution plate 5 also serves as a support element for the end plate 8. The distribution element 5 can possibly be corrugated and can also function to neutralize possible sound resonances in the gas flow or as a flame arrester or barrier should they backfire into the gas inlet side of the plate 1, e.g. as a result of damage (cracks) in the burner plate. If so desired, the holes 2 can have a conical entrance 6 and a cylindrical exit 7 or vice versa (plate upside down) : a cylindrical entrance and a conical exit.

A distribution element 5 is by preference also provided for the gas supply, along with an end plate 8 in the cylindrical device according to figure 3. Due to the flexibility of the membrane plate 1 with hole pattern 2, cylinders of relatively small diameters can be bent from flat plates.

It has been found that with certain forms of burner housings and built-in constructions in the spaces to be heated up (e.g.

boilers), resonance can occur at relatively high powers: e.g. over 1000 kW/m^2. It also appears that excess air in the gas mixture supply can have an influence on the tendency to resonate, along with the fact as to whether the gas is either drawn (suctioned) or blown through the membrane. Finally, the pattern of holes utilized in the membrane itself can also play a role in the resonance phenomenon.

The resonance phenomenon is presumably related to the high pressure gradient of the gas mixture between the relatively cold under side (inlet side) of the burner membrane and the very hot upper side (exit side : burning surface). By changing the flow rate variables, such as excess air and gas mixture flow rate, an oscillation phenomenon presumably occurs between the flame front (i.e. the level of the flame bases) and the gas mixture entering the holes. The tongues of flame therefore can dance up and down above the burner surface or even oscillate with their flame bases between a position in (or even under) the holes and a position above the holes (above the burning surface). This can be accompanied by annoying whistling sounds ranging from 1000 to 1500 Hz. This drawback can also be encountered when changing a burner from a blown gas to a drawn gas system.

As mentioned before it is an object of the invention to eliminate this disadvantage and to make the occurrence of whistling sounds less critical. The measure taken, however, should not reduce any of the other advantages of the concept with perforated burner membrane. In particular, the measure should not result in a drastic increase in the total pressure drop over the burner or a (local) destabilizing of the flame front.

The solution according to the invention consists of providing a gas burner device which includes a housing comprising the

following elements, positioned in succession downstream one after the other: means of supply for the gas which is to be burned, a distribution element, at least one acoustic muffling layer through which gas can pass, and a porous plate as burner membrane provided with a regular pattern of holes that, taken together, make up 5 % to 35 % of the surface area of the plate, with each hole having a surface area of between 0.03 mm² and 10 mm².

Details will be explained on the basis of a number of embodiments, thereby referring to figures 8 and 9. The embodiments are to be understood only as examples.

The gas burner device according to figure 8 includes a housing 16 with the following elements positioned in succession downstream from one another : a supply duct 15 for the gas mixture and a distribution element 5 in the form of a perforated metal plate which lies against the bent edge 22 of said supply duct 15. The housing 16 is attached to the supply duct with a weld 17. The distribution plate 5 is, for example, 0.4 mm thick and provided with holes 18, each having a diameter of 0.4 mm. The holes or passages 18 can be placed in the corner points of a pattern of adjacent equilateral triangles with a triangle side (i.e. pitch between the holes) of 1.25 mm. This means a free passage surface area of the plate 5 of approximately 10 %. Depending on the circumstances, this free surface area could just as well lie between 5 % and 20 %. Below 5 %, the pressure drop becomes too high at high gas flow rates; above 20 % the distribution effect for the gas mixture becomes insufficient at low flow rates.

Against the outlet side of distribution element 5 lies a welded wire mesh 13 of stainless steel wire with a wire diameter of, for example, 0.125 mm and a gas permeability of 48 mesh. Depending on the circumstances, a permeability can be chosen of between 30 mesh

and 60 mesh. Two or more meshes 13 can also be stacked on top of one another, preferably of different permeabilities.

Downstream from the welded wire mesh (or meshes) 13, which operates as an acoustic muffling layer, is the porous membrane plate 1, which is provided with a regular pattern of holes 12. This porous plate is again preferably a sintered metal fiber plate in which the fibers are heat-resistant, i.e. resistant against the high burner temperatures occurring during operation and resistant against thermal shocks. The fibers, therefore, are preferably steel fibers with a suitable Cr and Al content: e.g. FeCrAlloy fibers as described hereinbefore.

Plate 1, for example, is 2 mm thick and has a porosity of 80.5 % between the holes. The fiber diameter in the example 2 below was 22 µm and the diameter of the cylinder-shaped punched holes was 0.8 mm, while the spacing between the centers of the holes (i.e. the pitch) was 1.5 mm. Plate 1 is clamped against the housing 16, with a ceramic mat 14 inserted between the two.

In order to minimize resonance with specific gas flow profiles in specially shaped burners for situations in which the gas mixture is being drawn (sucked) and/or for specific construction parameters related to the combustion space to be heated, consideration can be given to providing an intermediate space 23 or 24 between the acoustically muffling layer 13 and the distribution element 5 and/or the membrane 1, respectively, as shown, for example, in figure 9. In this way various embodiments of the device are thus created. The device can, for example, include one muffling layer 13 that is in surface contact with the distribution element 5. In another embodiment the layer 13 can be in surface contact with both element 5 and porous plate 1.

Another possibility is to build up the muffling layer 13 as a laminate made up of two wire meshes 25 and 26 with a porous mass interposed between them. If so desired, the porosity, and therefore also the pressure drop over this laminate, can be changed under the influence of the gas pressure of the incoming mixture or via external operating means (not shown). The porous mass 27 can, for example, be a resilient mass of fibers, e.g. steel wool. Besides a more intense distributive effect on the mixture, this transverse compression respectively relaxation of the laminate can decrease the pressure drop over the membrane 1 at high flow rates so that again the danger of resonance becomes less critical.

According to another embodiment, the muffling layer 13 can consist wholly or partially of a porous mass of fibers 27. If so desired, this mass can fill up the whole interspace between plate 1 and element 5. By preference, mineral fibers are to be utilized (e.g. rockwool or steel wool).

Finally, the porous plate 1 can also include a laminate of wire meshes sintered to one another. Woven or knitted wire meshes of heat-resistant wires can be used for this purpose. A suitable laminate structure is described in U.S. patent 3.780.872. On the whole these laminates will be more rigid than those made of sintered fiber webs. Therefore they are mounted by preference in flat burners. A pattern of holes is of course also punched through these laminates as described above.

When the gas burner devices are intended only for operation at relatively low powers, or when the tendency to resonate does not per se need to be avoided, then sintered porous plates 1 as such - made of shavings or cut fibers, or else of wire meshes such as described above - can also be utilized. In this case a muffling layer 2 is not required and embodiments according to or analogous

to those described in the Belgian patent application 09200209 are then applicable. Instead of FeCrAlloy fibers, ceramic fibers or wires can also be used.

EXAMPLE 1

A flat sintered porous metal fiber plate 1 produced according to the invention and possessing the characteristics given below can be used as a membrane for a gas burner device. The characteristics and advantages of this concept with respect to previously presented burner membranes are explained below.

The steel fibers to be used are resistant against high temperatures and, for this purpose, contain by percent weight, for example, 15 to 22 % Cr, 4 to 5.2 % Al, 0.05 to 0.4 % Y, 0.2 to 0.4 % Si and at most 0.03 % C. They have a diameter of between 8 and 35 μm - for example, approximately 22 μm. The fibers can be obtained by a technique of bundled drawing, as known, for example, from U.S. patent 3.379.000 and as is mentioned in U.S. patent 4.094.673. They are processed into a non-woven fiber web according to a method described in or similar to the method which is known from U.S. patents 3.469.297 or 3.127.668. Afterwards, these webs are consolidated by pressing and sintering into a porous plate 1 with a porosity of between 78 % and 88 %. Porosities of 80.5 %, 83 % and 85.5 % are very common.

It is also possible to use thicker metal fibers as heat-resistant fibers in the porous plate, e.g. fibers with equivalent diameters of between 35 and 150 μm and consisting of wire shavings or cuttings from a plate of the desired heat-resistant alloy (e.g. FeCrAlloy). These fibers look rather like steel wool and can be manufactured according to a shaving process as disclosed e.g. in U.S. patent 4.930.199.

This porous plate 1 is now placed in a mould and, with a suitable punching device (stamp with punching pins), it is provided with a regular pattern of perfectly delimited circular cylindrical passages or holes 2 having a diameter of, for example, 0.8 mm. With a pitch of 2 mm between every pair of adjacent holes, a free surface area of nearly 15 % is obtained. Compared to a plate without holes, this design increases the flexibility and thus at the same time it facilitates the process of shaping, for example, into cylinders. The holes also form barriers against the spreading or propagation of cracks that may form in the membrane plate 1 as a result of the fluctuating thermal stress during operation. If so desired, the pattern of holes can be supplemented with a waffle pattern such as is described in EP 390.255.

Whenever holes are to be punched in solid steel plate, the thickness of the plate must always be thinner than the diameter of the holes. Surprisingly however, it has been found that this is not required for the punching of holes in the porous plates according to the invention. Thus there is a broad range of choice for the ratio of plate thickness to diameter or size of the holes or passages.

The great advantages of the invention concept, however, appear when the gas mixture to be burned is passed through the porous membrane plate 1. Indeed, the gas mixture now flows mainly through the holes 2, because of which the pressure drop over the membrane 1 is noticeably lower (than for plates without holes) for a particular flow rate or by which higher flow rates - and consequently larger thermal outputs or powers - can be achieved for a particular pressure drop value. The power range can now be selected between 150 and 900 kW/m^2 for a radiant surface combustion and can be increased to that of a blue flame surface burner with an output or power of up to 4000 kW/m^2, depending on factors such as

the excess air in the gas mixture in relation to a stoichiometric gas combustion mixture.

The porosity of the plate 1 results in the fact that a small portion of the gas always penetrates through the pores between the holes 2 to the hot exit surface. As explained below, this greatly promotes a uniform and stable burning over a broad load or power range. Especially at higher flow rates, the portion of gas that passes between the holes through the plate increases proportionally. It is now precisely at these higher flow rates (and consequently higher powers if the percent of excess air remains the same in the gas mixture) that the tendency to blow away the blue flame at the level of the holes needs to be counteracted. The burning of the gas at the surface of the plate between the holes 2 maintains, as it were, a stable (blue) flame front over the whole plate surface and prevents this front (or the blue flame tongues within it) from being blown away from the plate surface. The tongue-shaped flames above each hole remain, as it were, with their base - or root - anchored to the plate surface.

The largely horizontal orientation of the fibers within the porous plate also promotes the isolating effect of the membrane. Indeed, the heat conduction runs primarily in the outside surface (radiant side) of the plate and much less in the depth (throughout the thickness) of the plate. Moreover, there is the ongoing uniform cooling effect of the cold gas supply in direct contact with the layer of fibers on the gas inlet side. In turn, this uniform heat distribution at the level of the plate surface promotes the uniform combustion of the gas layer and a stable burning state over a broad load or power range at the exit side of the plate between the consecutive holes 2. With a porous membrane layer 1, that on its gas inlet side is attached, for example, to a supporting steel plate and in which the porous layer together with the support

plate have the same pattern of holes, this isolating effect will on the whole be smaller and the powers that can be attained will be lower. On the other hand, with another variant embodiment : a porous membrane without holes that is attached to a gas distribution plate support with a regular pattern of many small holes (e.g. hole diameters of 0.3 mm and a pitch or center-to-center distance of adjacent holes of 1.25 mm), the attainable gas flow rate for a given pressure drop will remain more limited than with the plate according to the invention. Further with this arrangement, the high powers per unit of burner surface area are not attainable.

Another advantage with respect to the known plate membranes without holes relates to the fact that now it is much less necessary - if at all - to pre-filter the gas being supplied since it passes mainly through the larger passages (holes) 2 and only to a very limited extent through the small pores in the plate 1. The membrane plates according to the invention also need to be cleaned with a reverse flow much less frequently than was the case with porous plates lacking holes or passages.

The plate thickness, its porosity and the size of the passages or holes must of course all be coordinated with one another so that for any burner state no backfiring towards the gas inlet side will occur.

In a burning test the following observations were noted for a sintered fiber plate 1 made of the known FECRALLOY fibers with a diameter of 22 µm. The plate was 2 mm thick, had a porosity of 80.5 % and was built into a gas burning device of the type illustrated in figure 2. A pattern of holes was punched into the membrane 1 as shown in figure 2: diameter of the cylinder holes was 0.8 mm and a regular geometric pattern of holes with pitch

p = 2 mm in a regular grid of adjacent equilateral triangles. The distribution plate 5 (0.4 mm thick) was at a distance of 5 mm from plate 1 and was provided with holes of 0.4 mm diameter and with a pitch of 1.5 mm. This resulted in a free passage surface area of 6.5 %. There were no sound resonances or whistling sounds during operation.

The pressure drop in the gas mixture over the plate (mbar) increases somewhat more rapidly than linearly with the resulting power (kW/m^2). At a pressure drop of 0.05 mbar, a power of 150 kW/m^2 was noted and at a pressure drop of 3 mbar, a power of 3500 kW/m^2 was attained. The gas mixture was composed of 8.1 % natural gas and 91.9 % air. Natural gas with a relatively low calorific value of 10 kWh/Nm^3 was used and a 30 % excess of air was applied.

A radiant surface burner state was noted up to something like 800 kW/m^2. At higher powers, the burning changed into a blue flame mode. The temperature of the membrane surface (gas outlet side) increased to approximately 850 degrees C at around 700 kW/m^2 and gradually fell when going to higher powers (blue flame mode) to approximately 600 degrees C. The membrane temperature on the gas inlet side remained below 150 degrees C and even decreased to below 100 degrees C in the blue flame mode. The measured NO_x emission (ppm) rose gradually over the whole power range up to 2000 kW/m^2. However, it was only about 10 ppm at 700 kW/m^2, and for powers around 2000 kW/m^2 and up, it stabilized at about 15 to 20 ppm. The measured NO_x values are in fact the data reduced to their value at 0 % 02 in the combustion gases. These very low NO_x values are probably to be explained by the fact that the flame tongues above the holes remain small so that the temperature in their cores remains relatively low. The CO content was nearly zero over the entire power range.

By way of conclusion, therefore, it has been found that for burner applications with the invention, a porous plate concept is available for the first time that can be used over an enormously broad power range and is therefore suitable both for surface radiant and blue flame modes. In addition, the concept offers remarkably low CO and NO_x emissions and it offers high yields.

Example 2

In the embodiment of figure 8 the porous plate 1 is in surface contact with the 48 mesh wire mesh 13. A gas mixture of natural gas and air was passed through the compact combination in housing 16 of this wire mesh 13 clamped together between the 2 mm thick porous plate 1 and the distribution element 5 with free passage surface area of 10% (both described above). The square burner surface measured 150 mm x 150 mm. Various proportions of excess air were utilized (1.1 to 1.3) and the flow rates were increased such that powers were developed ranging from 500 kW/m^2 to 5000 kW/m^2.

In the table below the resonance results are given in column [1 + 2 + 3]. By way of comparison, the burning tests are repeated in the table for embodiments with a combination of only plate 1 and distribution element 5: column [1 + 3] and for the embodiment without wire mesh 13 and without plate 5: column [1]. The minus sign in the table refers to the desired absence of whistling sounds during burning, while the plus sign indicates the presence of an annoying whistling sound. Whistling sounds, moreover, indicate an oscillation of the flame bases 20 in the holes 12 as suggested with arrow 21.

TABLE 1

LOAD [KW/m²]	EXCESS OF AIR [n]	[1]	[1+3]	[1+2+3]
500	1.1	-	-	-
	1.2	-	-	-
	1.3	-	-	-
1000	1.1	+	-	-
	1.2	-	-	-
	1.3	-	-	-
2000	1.1	+	+	-
	1.2	+	-	-
	1.3	-	-	-
3000	1.1	+	+	-
	1.2	+	+	-
	1.3	+	-	-
4000	1.1	+	+	-
	1.2	+	+	-
	1.3	+	+	-
5000	1.1	+	+	-
	1.2	+	+	-
	1.3	+	+	-

We can infer from the table that a smaller excess of air (1.1) results more readily in resonance than does a larger excess of air (1.2 or 1.3). Moreover, the favorable effect of wire mesh 13 appears to show up especially with the higher power loads (above 1000 kW/m²).

CLAIMS

1. A porous metal fiber plate (1) characterized in that a regular pattern of holes or passages (2) has been made in it which occupy an overall free passage area of 5 % to 35 % of the total surface area of the plate, while each hole (2) has a surface area of between 0.03 mm^2 and 10 mm^2.

2. A plate (1) according to claim 1 with a thickness of between 0.8 mm and 4 mm.

3. A plate according to claim 1, in which the holes (2) have a circular cylindrical shape with each a surface of between 0,03 and 3 mm^2.

4. A plate according to claim 1 in which the passages are slots (9 to 11) with each a surface area of between 1 and 10 mm^2.

5. A plate according to claim 1 in which both slots (9, 11) and circular openings (2) are present.

6. A plate according to claim 1 with a porosity between successive passages is situated between 60 % and 95 %.

7. A plate according to claim 6 with a porosity of between 78 % and 88 %.

8. A plate according to claim 1, in which the metal fibers are resistant against high temperatures and have an equivalent diameter between 8 and 150 μm.

9. A plate according to claim 8, in which the metal fibers are steel fibers containing aluminum and chrome.

10. A plate according to claim 3, in which the holes have a surface area of between 0.5 and 0.8 mm^2.

11. A plate according to claim 3, in which said free passage surface area amounts to between 8 % and 16 %.

12. A plate according to claim 11, in which the successive holes (2) are arranged in a pattern of equilateral triangles in which each hole (2) contains a corner point of the triangle.

13. A plate according to claim 4 in which the slots are substantially rectangular with a width "w" of between 0,4 and 2 mm and a length "l" of between 3 and 20 mm.

14. A plate according to claim 13 in which the slots have a width 0,5 mm $\leq w \leq$ 1 mm and a length 5 mm $\leq l \leq$ 10 mm.

15. A plate according to claim 13 or 14 in which the overall free passage area occupies 20 % to 30 % of the total surface area of the plate.

16. The application of a plate (1) according to claim 1 as a membrane for gas burning.

17. The application of a plate (1) according to claim 16, in which the passages (2) have a circular cylindrical shape with each a surface area of between 0,03 and 3 mm^2.

18. The application of a plate (1) according to claim 16, in which the passages (2) are slots with each a surface area of between 1 and 10 mm^2.

19. A gas burner device comprising a housing (3) with supply means (4) for the gas to be burned, a distribution element (5) for the gas and a porous plate (1) as a burner membrane provided with a regular pattern of holes (2, 9 to 11) which occupy an overall free passage area of 5 % to 35 % of the total surface area of the plate, whereas each hole or passage has a surface area of between 0,03 and 10 mm^2.

20. A gas burner device according to claim 19 which includes a housing comprising the following elements, positioned in succession downstream from one another: means of supply (15) for the gas which is to be burned, a distribution element (5), at least one acoustic muffling layer (13) which is permeable for gases and a porous plate (1) as burner membrane provided with a regular pattern of holes (12) that, taken together, make up 5 % to 35 % of the surface area of the plate, whereas each hole or passage has a surface area of between 0.03 mm^2 and 10 mm^2.

21. A device according to claim 20, in which the acoustically muffling layer (13) includes at least one wire mesh.

22. A device according to claim 20, in which the muffling layer (13) consists either wholly or partially of a porous mass of fibers (27).

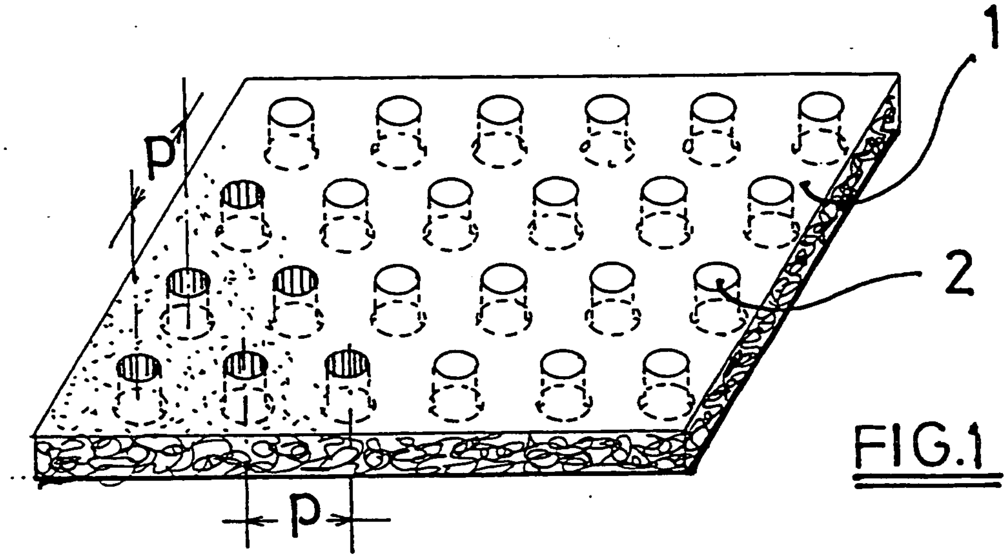

FIG.1

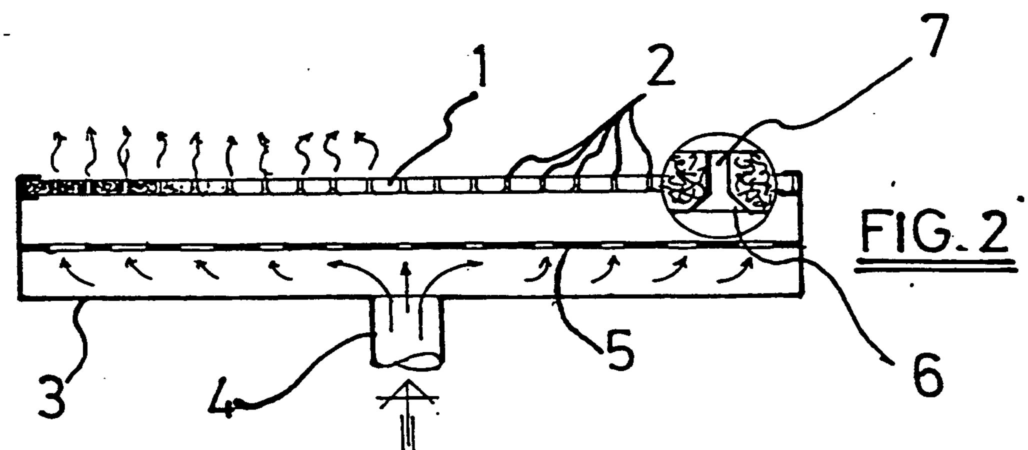

FIG.2

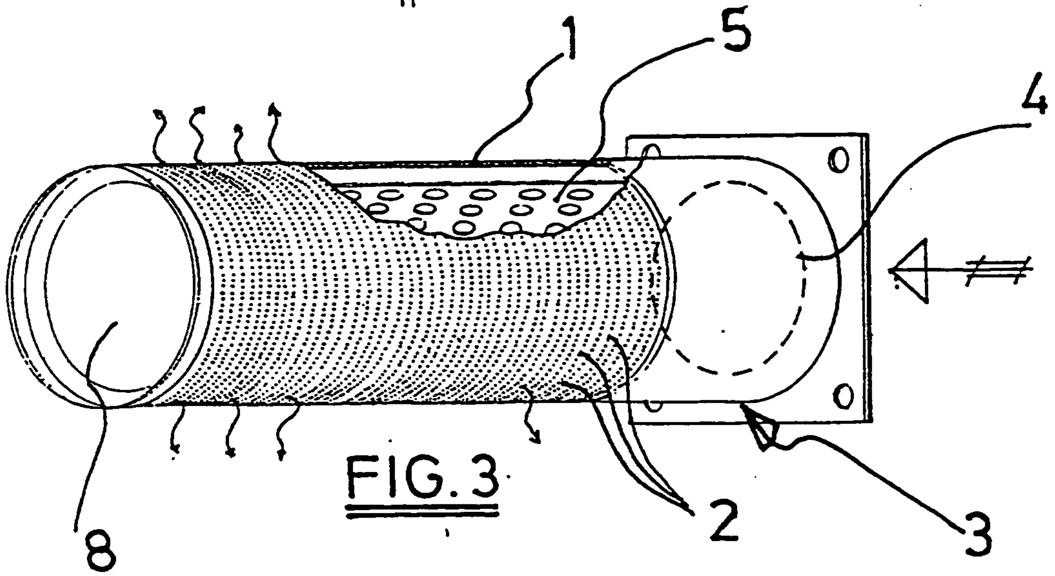

FIG.3

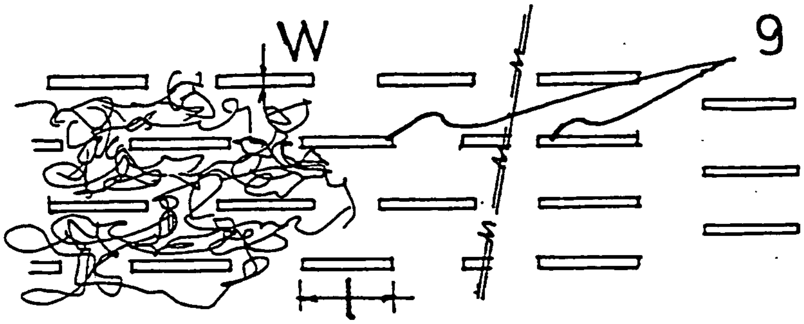

FIG. 4

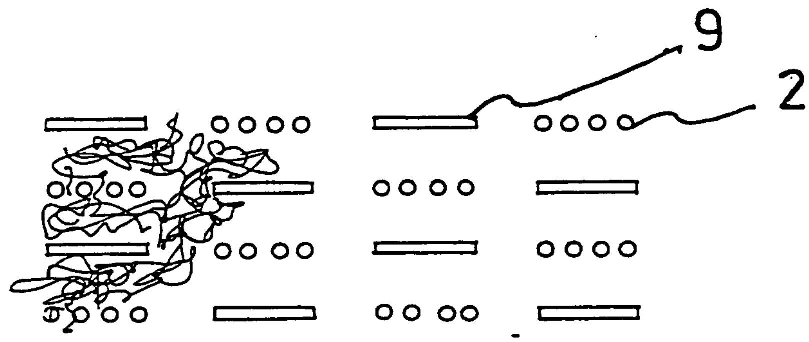

FIG.5

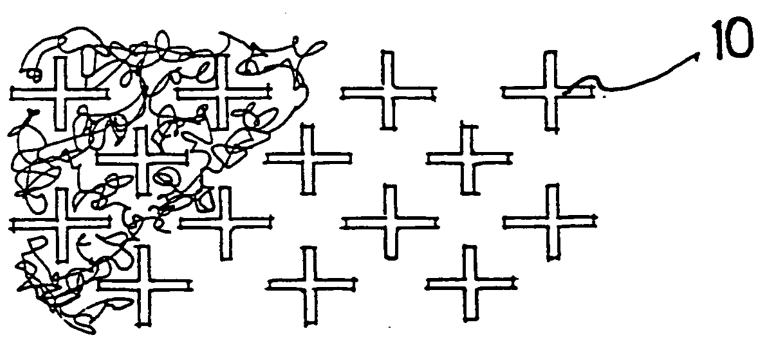

FIG.6

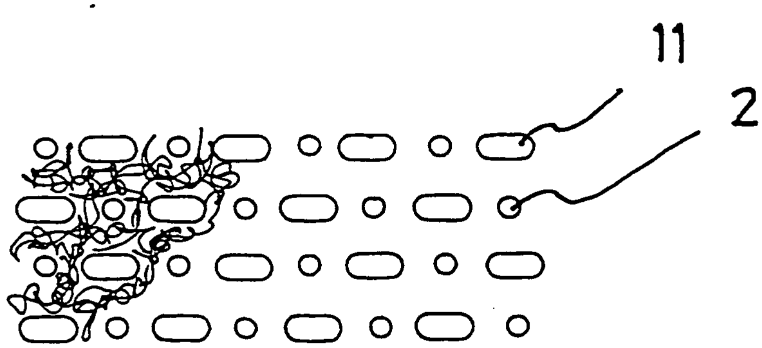

FIG. 7

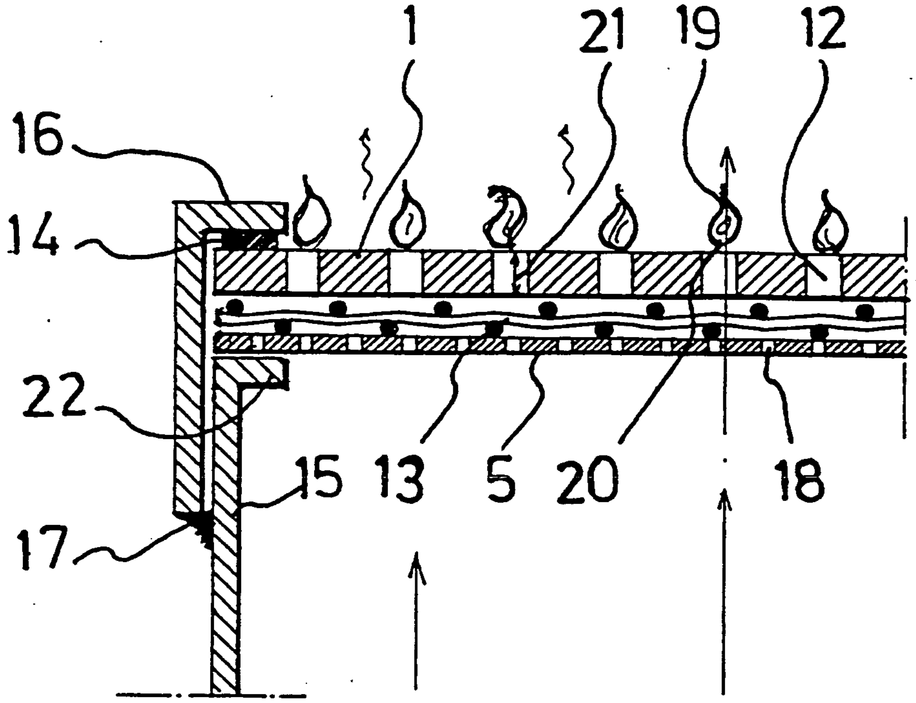

FIG. 8

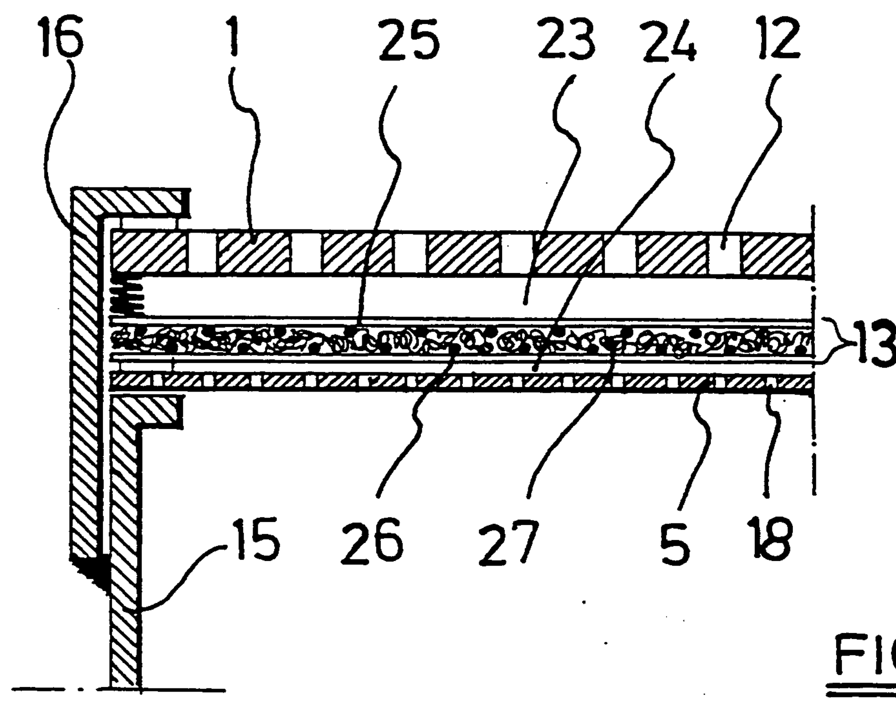

FIG.9

INTERNATIONAL SEARCH REPORT

International Application No PCT/BE 93/00010

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 F23D14/16; F23D14/18; F23D14/14

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	F23D ; B22F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
P,A	EP,A,0 526 351 (APPLICATION DES GAZ) 3 February 1993 see page 3, line 8 - page 4, line 2 see figures 1,2 ---	1,3,16, 17,19
A	PATENT ABSTRACTS OF JAPAN vol. 9, no. 158 (M-393)(1881) 3 July 1985 & JP,A,60 33 415 (MATSUSHITA DENKI SANGYO) 20 February 1985 see abstract ---	1,3,10, 12,16,17
A	US,A,4 063 873 (NAITO) 20 December 1977 see claims 1-6; figure 1 ---	1,3,12, 16,17
A	EP,A,0 390 255 (BEKAERT) 3 October 1990 cited in the application ---	

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° Special categories of cited documents :[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
19 MAY 1993	26. 05.93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	VRUGT S.C. Vrugt

International Application No PCT/BE 93/00010

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category°	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	EP,A,0 157 432 (SHELL) 9 October 1985 cited in the application -----	

Form PCT/ISA/210 (extra sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. BE 9300010 SA 70277

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0526351	03-02-93	FR-A-	2679981	05-02-93
US-A-4063873	20-12-77	JP-C-	1078226	25-12-81
		JP-A-	52050036	21-04-77
		JP-B-	56019524	08-05-81
		AU-B-	507275	07-02-80
		AU-A-	1868576	20-04-78
		GB-A-	1518624	19-07-78
EP-A-0390255	03-10-90	CA-A-	2012261	29-09-90
		JP-A-	3110312	10-05-91
		US-A-	5088919	18-02-92
EP-A-0157432	09-10-85	CA-A-	1249214	24-01-89
		DE-A-	3566832	19-01-89
		JP-B-	4067090	27-10-92
		JP-A-	60213717	26-10-85
		US-A-	4597734	01-07-86

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82